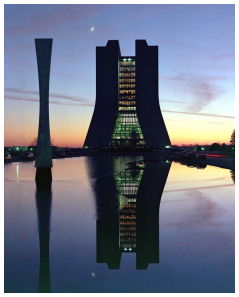

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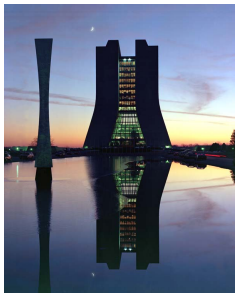
Muon Accelerator Program

Analyze Breakdown in All Seasons Cavity

K. Yonehara

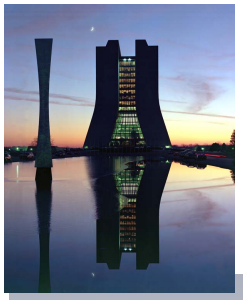
APC, Fermilab



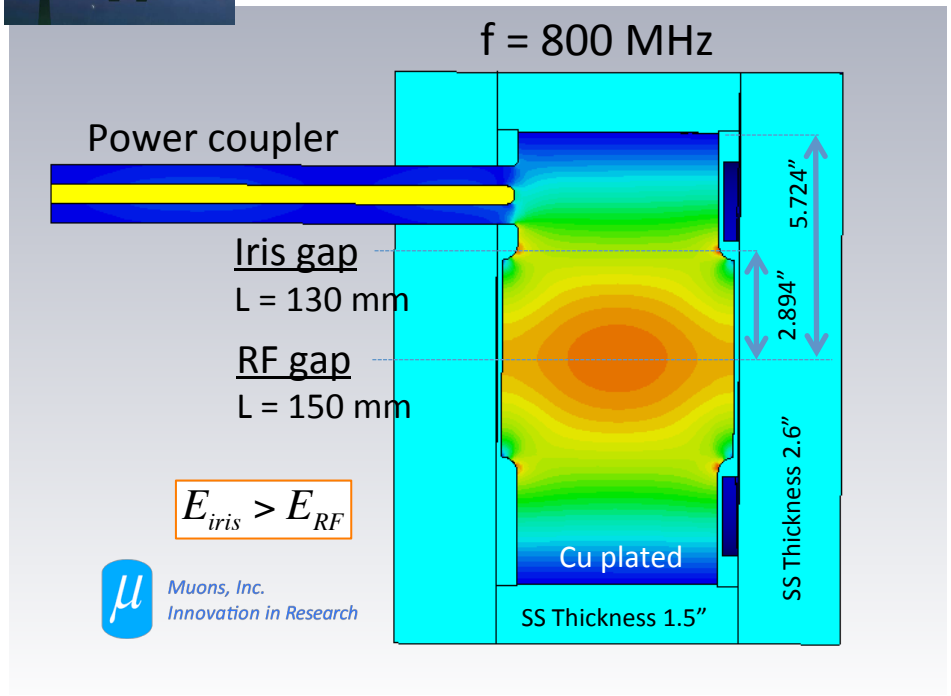
Introduction

- All Seasons Cavity (ASC) test is very special
  - Longer accelerating gap (L = 150 mm) than usual (L = 100 mm)
  - Operating rep rate (1 Hz) is very low to avoid heating
  - Limited breakdown event to avoid unrecoverable damage
  - As a result, we could see a unique breakdown result
- Analyze breakdown process in the ASC
  - Study electron dynamics in such a long accelerating gap
  - Breakdown pit analysis

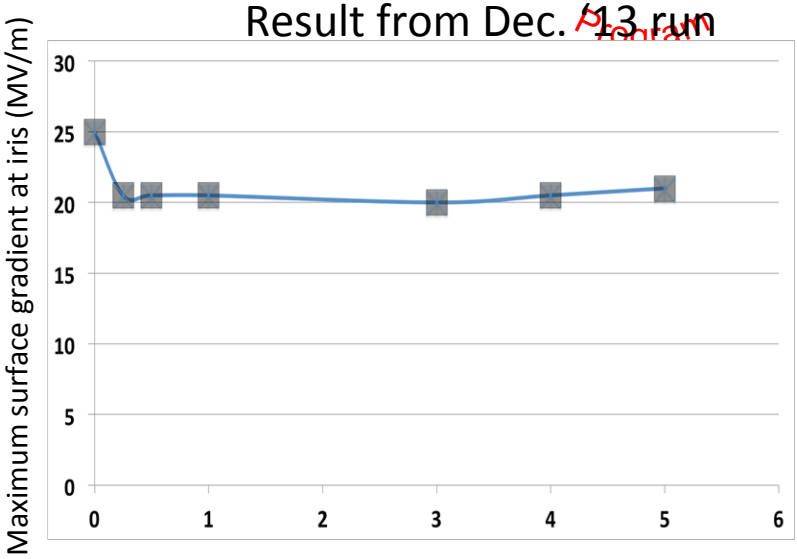
• No visible BD damage on the power coupler after the December test

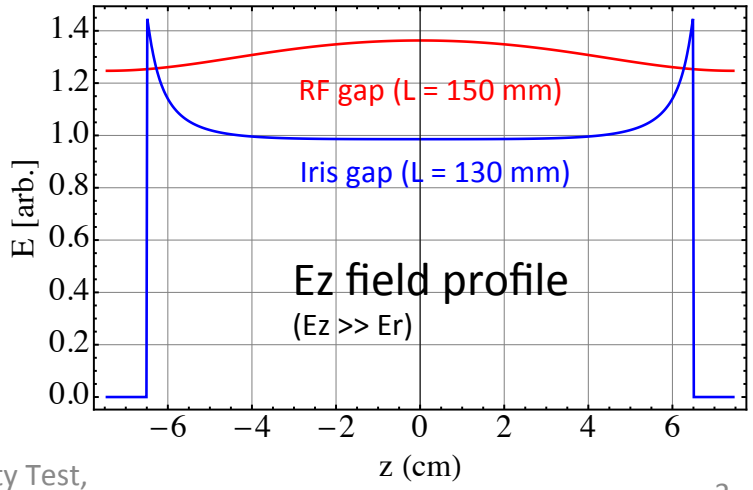


Profile of ASC



Result from Dec. 13 run

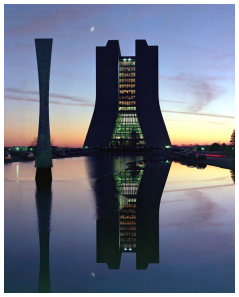




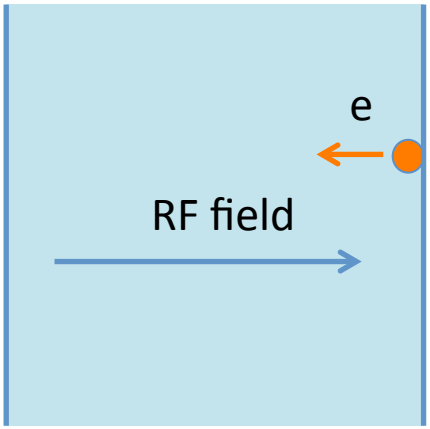
Field enhancement:

- Surface grad at RF gap = 1.25
- Surface grad at iris gap = 1.42

Thus, the observed maximum gap 22 MV/m (iris) corresponds to 19.4 MV/m on the RF gap surface



Electron dynamics

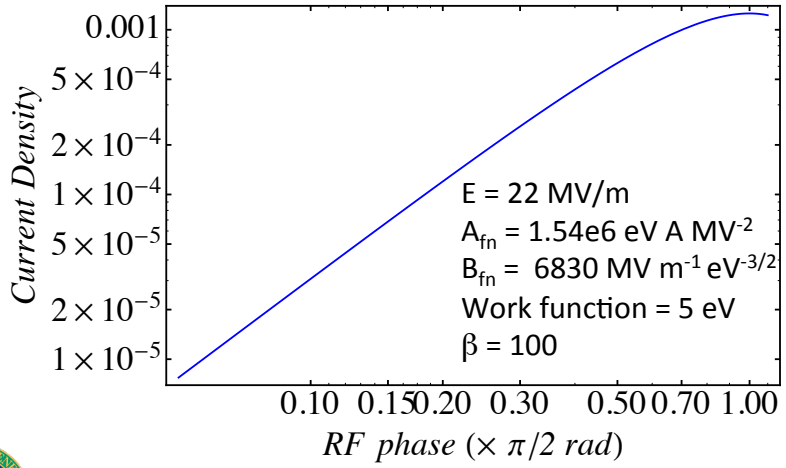


- Consider only surface emission electrons
- Electrons are accelerated by RF field

$$\beta'(t) = \frac{cE_0 \sin(2\pi ft + \phi_0)}{m_e}\left(1-\beta^2(t)\right)^{3/2}$$

- They arrive at other RF wall and release their kinetic energy as an impact energy

$$K = (\gamma - 1)m_e$$

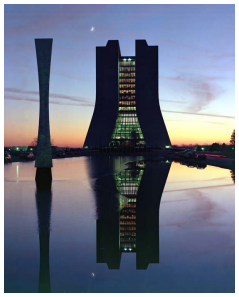


Fowler-Noldheim formula

$$i(\beta E) = \frac{A_{fn}(\beta E)^2}{\phi} Exp\left[-\frac{B_{fn}\phi^{3/2}}{\beta E}\right]$$

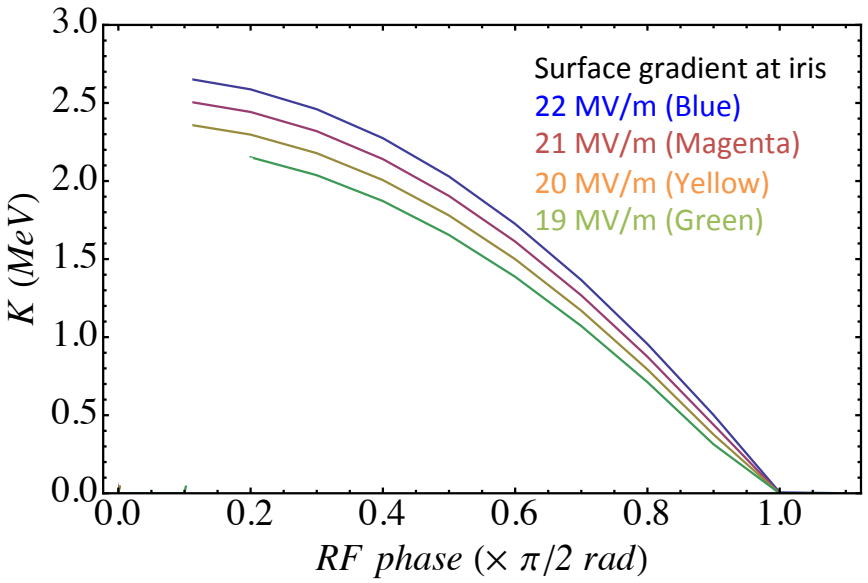
Impact energy

$$p(E) = i(\beta E)K(E)$$

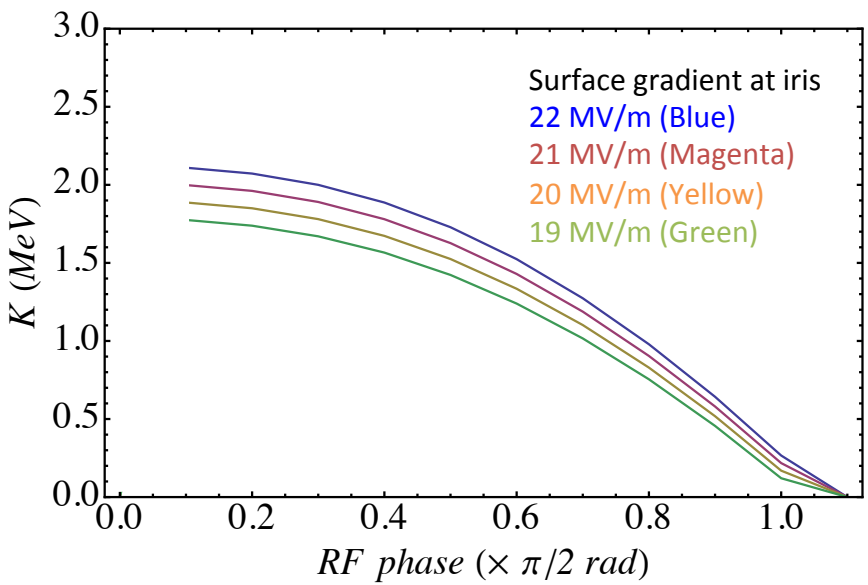


Calculate kinetic energy of electron arriving at other RF window as a function of initial RF phase

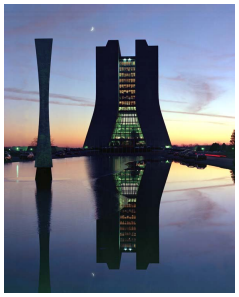
RF gap



Iris gap

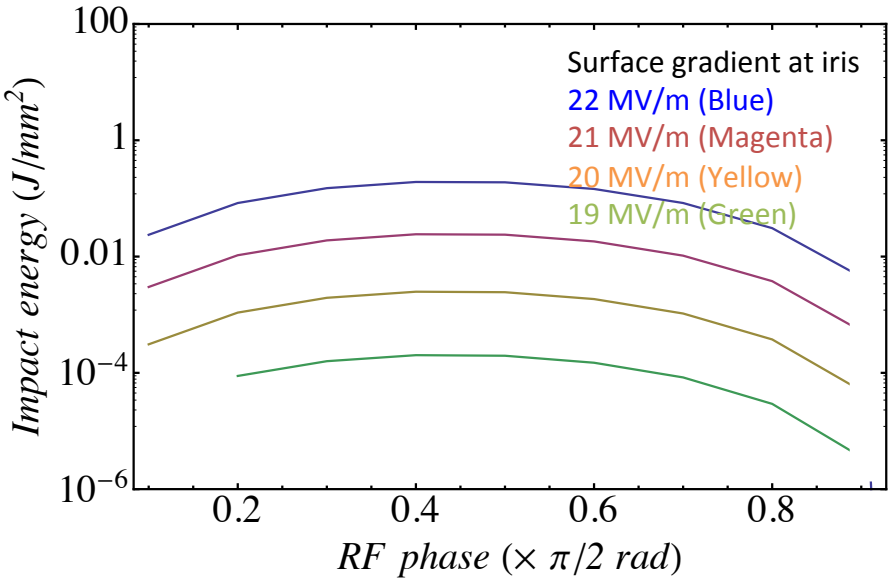


- Kinetic energy in the RF gap is ~ 20 % higher than that at the iris
- Kinetic energy in the RF gap is zero at initial RF phase π/2
  - ▷ Electrons cannot reach to other RF window at this phase
- Ignore electrons which is emitted at zero initial RF phase
  - ▷ FN shows no dark current generated at zero RF phase

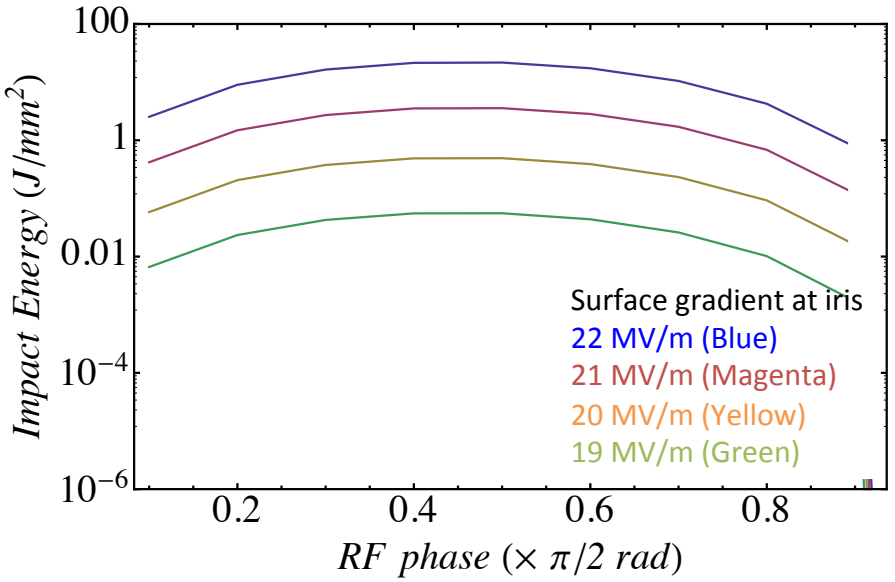


Calculate Impact energy of electron arriving at other RF window as a function of initial RF phase

RF gap

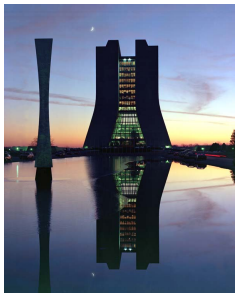


Iris gap

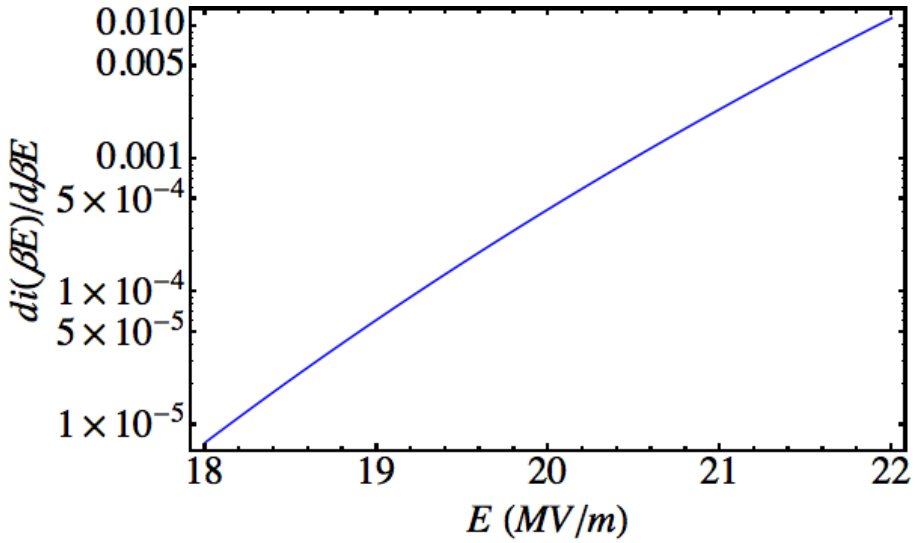


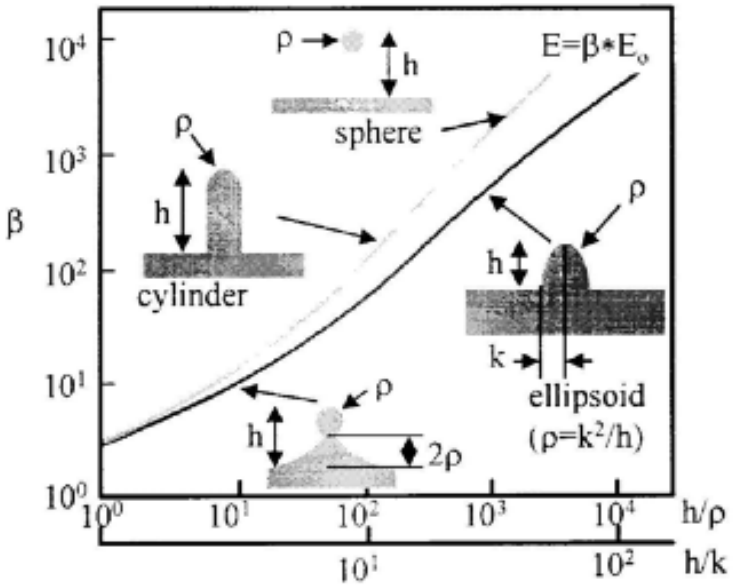
- Impact energy at the iris gap is <u>two orders of magnitude</u> larger than that at the RF gap!
- Maximum impact energy is happened at the initial RF phase 45 degrees

If this analysis model is true, then the most breakdown events should be taken place at the iris gap!!
↔ However, the breakdown pit distribution does not support the model…

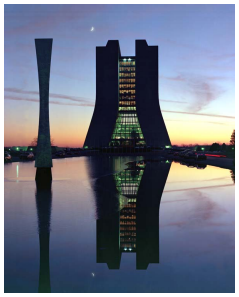


Why impact energy at iris gap is so large?

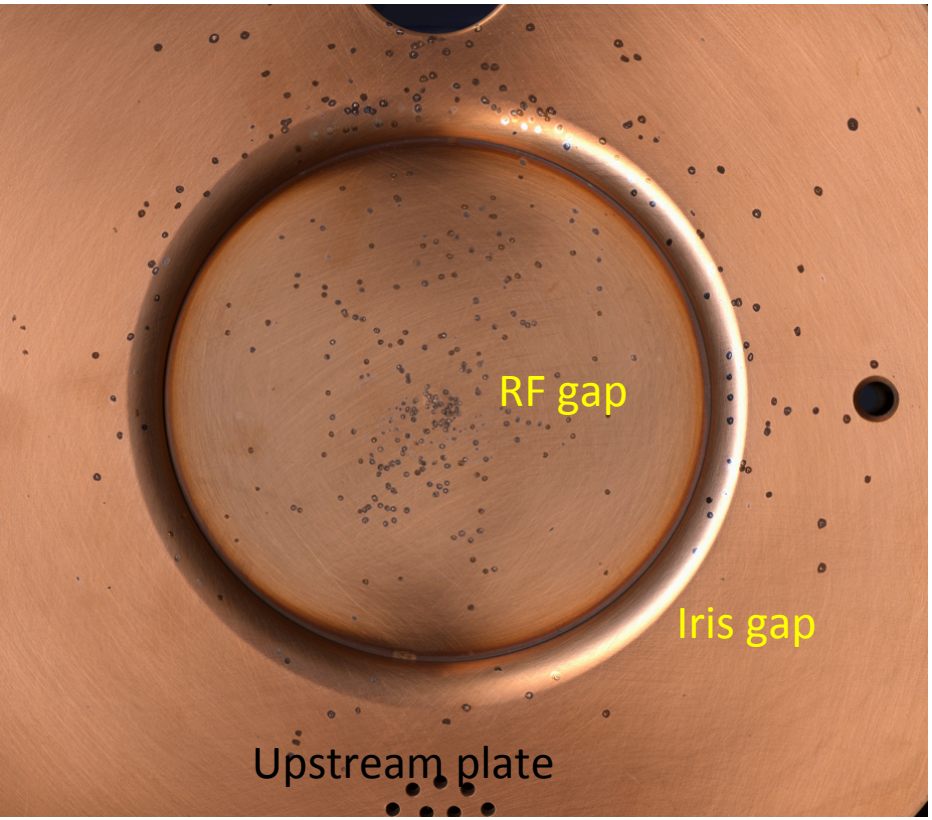


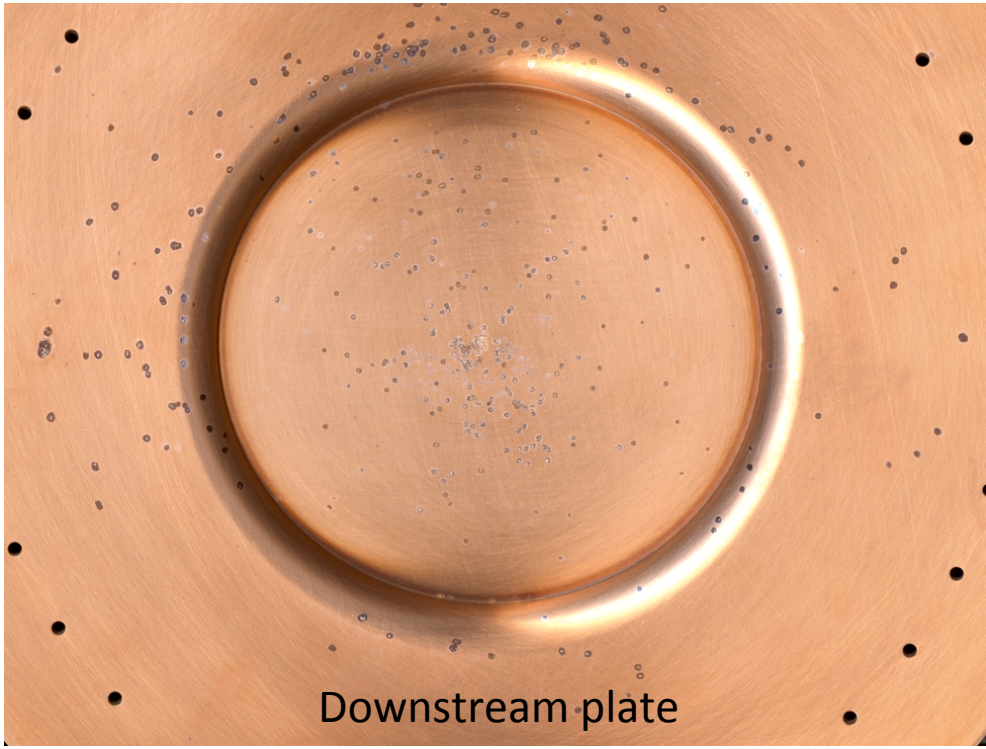


Surface grad at the iris is 15 % higher than that at the RF one.
If the field enhancement factor β is uniform in the cavity the breakdown probability at iris is the highest.
However, if the field enhancement becomes low by 15 % at the iris during conditioning what happen then?
βE becomes equal between at the RF gap and at the iris so that the breakdown could take place at the RF gap.

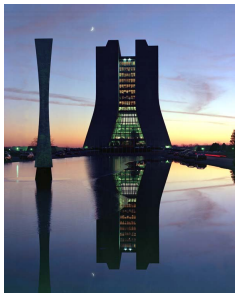


Breakdown Pits are found everywhere in ASC



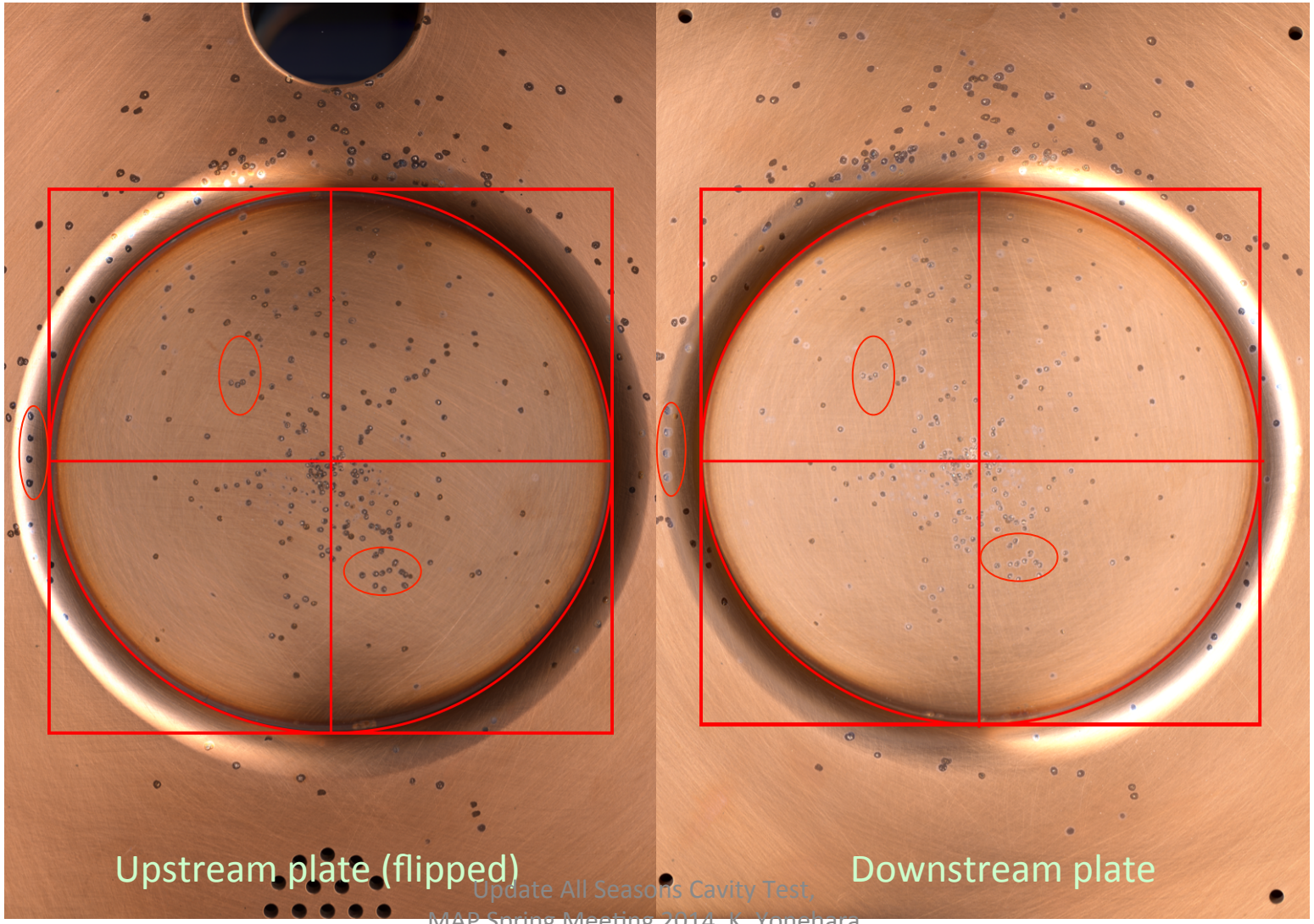


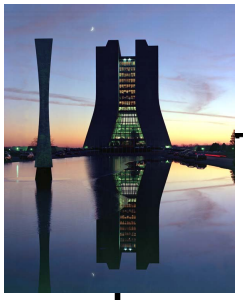
We can see a breakdown pit at the RF gap as well as at the iris gap



Identify BD pits

Limited the number of breakdown events to avoid unrecoverable dama
→ We can identify a pair of breakdown pits on both end plates



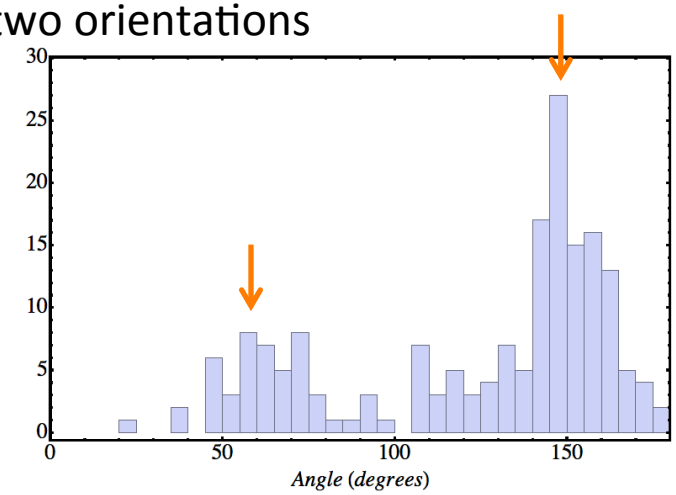


Red: Downstream plate
Blue: Upstream plate

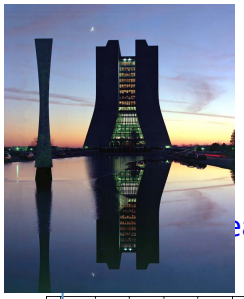
Map breakdown pits

In fact, the pit is uniformly distributed

We also noticed that the pit pair has two orientations

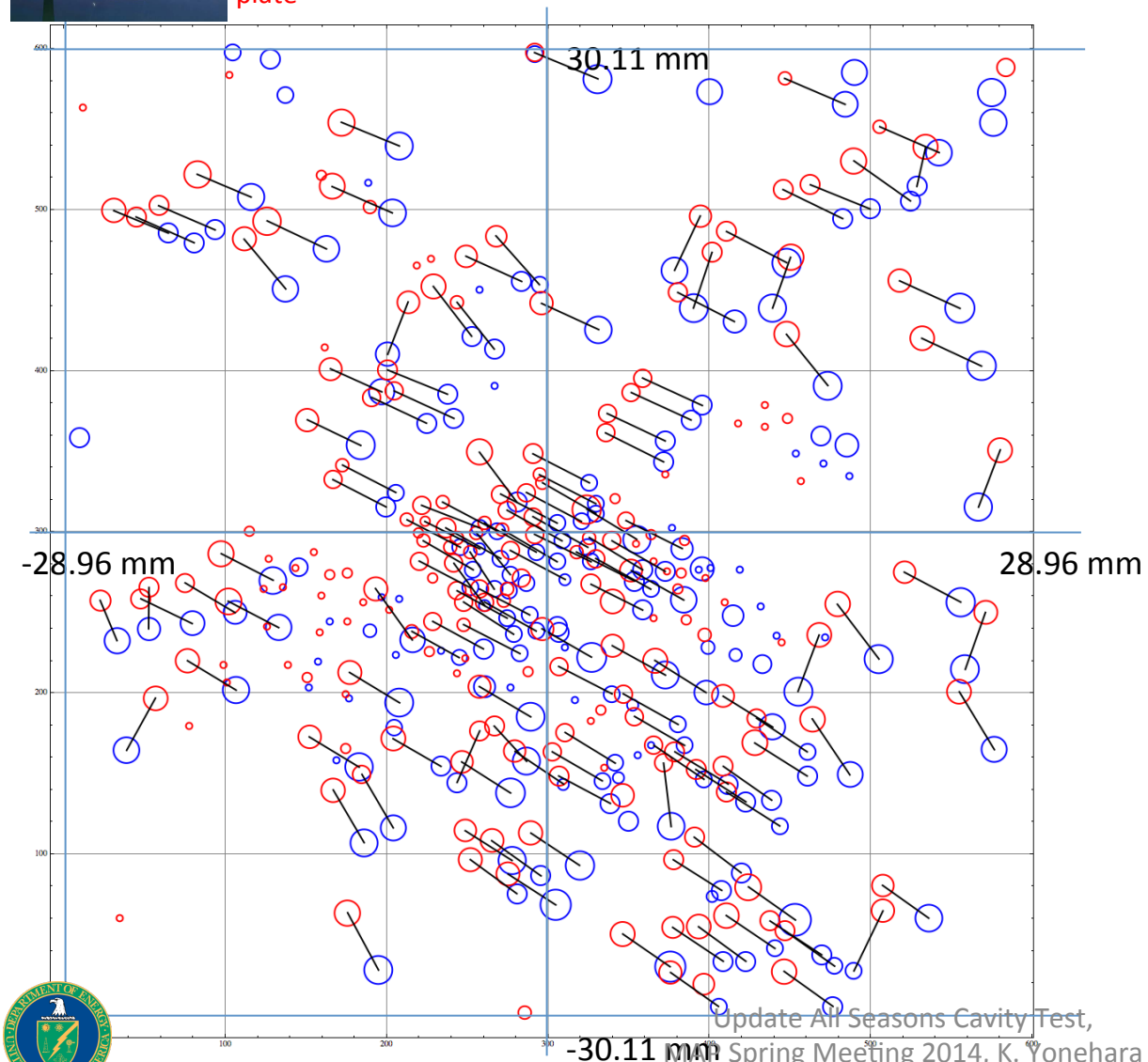


The pit pair which has ~ 60 degrees seems to be distributed on the iris gap



Breakdown pit image at RF center

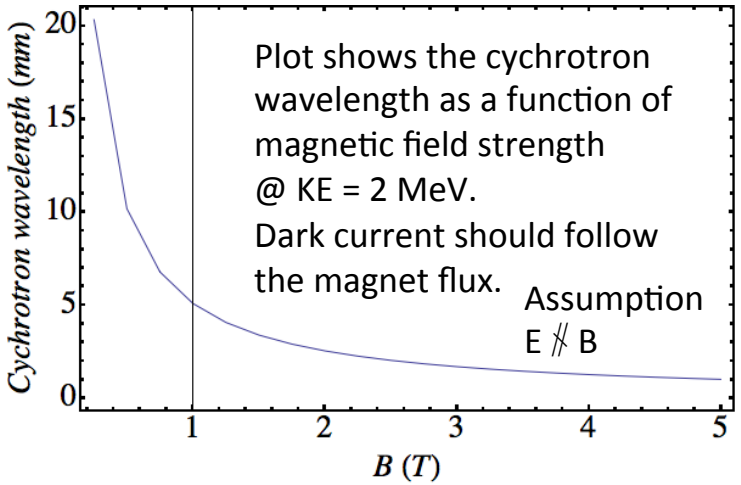
eam plate
plate



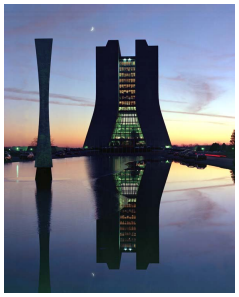
The pit pair which has 150 degrees is dominant at RF center

Possible breakdown process

- ASC was conditioned without magnetic field
- Many BD pits were generated around the iris gap in conditioning
- βE at iris and βE at RF gap became equal
- Magnet was turned on
- Another BD pits were generated at the RF gap as well as the iris gap



If this hypothesis is correct, the pit pairs that are the angle ~ 60 degrees are generated without the magnetic field while the other pit pairs that are the angle ~ 150 degrees are generated with the magnet



Conclusion

- Hypothesis is proposed to explain why two orientations of pit pair are made
- If hypothesis is correct the observed E_{iris} with B (slide 3) should represent the true cavity performance (with L = 150 mm) in multi-tesla fields

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